8,000 K. W. TURBO-ELECTRIC POWER STATION DESIGN

BY

T. K. MIECZKOWSKI

H. P. SEEBERGER

ARMOUR INSTITUTE OF TECHNOLOGY

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A THESIS

PRESENTED BY

THADDEUS K. MIECZKOWSKI

HARRY F. SEEBERGER

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ELECTRICAL ENGINEERING

1915

Eng.

PREFACE

The essential problem in the subject of the "8000 K. W. Turbo-Electric Power Station Design" is to provide a comparatively simple lay-out of Power Station with good and durable engineering work at a reasonable initial cost of construction and with minimum subsequent working expenses.

T A B L E   O F   C O N T E N T S

LIST OF DRAWINGS

SELECTION OF GENERATING UNITS

L O A D   C U R V E

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SELECTION OF GENERATING UNITS

The first point to be considered in the design of the plant is the selection of the proper generating units from a study of the load curve. According to the load curve, the twenty-four hour day may be divided into three periods. From 12:00 Midnight to 6:00 A. M., the load is about 2300 K. W. From 6:00 A. M. to 10:00 A. M., the load rises to a little over 5200 K. W., and remains nearly constant until 5:00 P. M., when it rises rapidly to a maximum of approximately 8000 K. W. at 7:00 P. M. The load now gradually decreases until midnight. For each of these periods, one or more 3000 K. W.generators may be used. For the first load of 2300 K. W., one 3000 K. W. generator may be used; for the second load of 5200 K. W., two 3000 K. W. generators are used, and for the peak load three 3000 K. W. generators

are used. As the load decreases the generated power is decreased by stopping one or more of the generators.

The plant contains four 3000 K. W. generators, the extra generator being supplied for any emergency or overload that may occur. The units were so chosen that at all times during the day there is an overload allowed for with the generators required for that particular load.

T H E   B U I L D I N G

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THE BUILDING

The outside dimensions of the building are: 144 feet in width and 184 feet in length. The height of engine room to the base of roof truss is 50 feet, and the height of boiler room to the base of roof truss is 60 feet.

Owing to uneven distribution of the heavy loads and effect of vibration due to the heavily loaded traveling crane as well as the vibration of the moving parts of machinery, the concrete structure was adopted for foundation. For the same reason the walls are constructed quite substantially, especially the one which separates the boiler room from the engine room. All walls, except the one which separates the engine room from the transformer compartments, are built of red fire brick, trimmed with Bedford stone.

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The wall which separates the boiler room from the engine room is 2 feet thick, while the outside walls are 18 inches in thickness. The engine room is separated from the transformer compartments by a 12 inch wall of white tile brick. This wall extends up to the floor of the first gallery.

The interior of the building is finished so that it will look clean, have good ventilation, good lighting and good drainage. The walls in the boiler room are left in neatly pointed brick work. The floor is of re-inforced concrete 12 inches thick.

The interior of the engine room is finished in white glazed brick. The floor of the engine room and the switchboard galleries are finished in limestone mosaic.

There is an opening in the floor located 4 feet from the boiler room wall 12-1/2 feet wide. It extends throughout the length of the

engine room except for 8 feet on either end, which is used as a passage way.

An iron stairway with wooden non-slip treads, so as to make it safe to walk on, is located at the center of the engine room and leads down into the basement through this opening. A 4 foot bridge across the opening at the stairway allows the passage to the boiler room. The basement floor which is 2 feet thick is finished in cement rendering.

The ventilation in the boiler room is accomplished through the ventilating louvres in the roof as well as through the doors and windows; while in the engine room large windows are the means of good ventilation. The windows are 10 feet wide and 14 feet high. The upper portion of each window is semi-circular. The windows are built in three vertical sections, the middle one of which is pivoted on a vertical axis. The control gallery is lighted by small rectangular windows.

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A repair workshop or tool room is provided, which contains a grindstone, lathe, drill press, punching and shearing presses, - all run by one motor. The corresponding bench is situated in the shop also. The superintendent-engineer's office is arranged in the engine room near the gallery. The lavatories, showers, and place for lockers are provided as well.

Roof trusses are supported by the walls of the building, which are stiffened by pilasters at the points where the trusses are set. To prevent longitudinal or lateral slipping, anchor bolts are used. The top chords of the trusses are tied together by the purlins, which support the roof. In the place of the upper and lower chords, rods are used for diagonal bracing.

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T H E B O I L E R R O O M

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THE BOILER ROOM

Steam is supplied at 175 lbs. pressure and 150 degrees F. superheat. These conditions were chosen as the best for the turbo units used. Feed water is to be supplied to the boilers at 200 degrees F. Under these conditions it was found that 6000 boiler horse power was needed to supply the trubines with the required amount of steam. For this purpose twelve Babcock and Wilcox boilers of 500 boiler horse power each were chosen. The boilers are arranged in two rows. There are six batteries; two boilers make a battery.

Each boiler is equipped with three steam drums and a superheater. Chain grate stokers are used, each bank of boilers having a reciprocating engine driving the stokers. The engines are located at the end of the banks of boilers. Mechanical stokers are employed; first, to dis-

pense with the services of expert firemen; secondly, to give more uniform temperature throughout the furnace; thirdly, to reduce the coal consumption. Also the combustion is more complete than with hand firing. This is due to the fact that the fire is continually stirred by the movement of the cars, and ashes are removed as fast as formed, giving a free supply of air.

The steam is delivered from the superheater through an expansion joint and valve to a header common to one battery of boilers. The headers from the various batteries lead directly into the 24 inch main header through a valve gate placed close to the main header. This header is supported by brackets on the boiler room wall. Each turbo unit takes steam directly from the main header.

Coal is delivered by the railroad on a track which enters into the boiler room. The track extends through the engine room also.

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The coal is dropped into the bunkers, each having its own crusher and bucket conveyor. There are two rows of bunkers, which are separated from each other for the purpose of light and ventilation.

The ash handling apparatus is located directly below the boilers. It consists of two bunkers; one for the fine coal and the other for the ashes. The fine coal is drawn off and is used again. The ashes are placed in the cars and removed by the railroad.

The chimneys are 12 feet in diameter and 220 feet high. They are steel chimneys lined with fire brick. They are set on a concrete base at each end of the boiler room. The flues are carried behind the boilers on light I - beams and lead directly into the chimneys.

T H E E N G I N E R O O M

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THE ENGINE ROOM

In the engine room are located the four alternators, of the General Electric type, each having a capacity of 3000 K. W. They are placed across the width of the room. Each of the alternators is supported by three concrete piers, these piers being independent of the floor of the basement. They are driven by six stage Curtis turbines exhausting into Wheeler surface condensers, each having a capacity of 9000 square feet. There is an open air exhaust located in the connection between the turbine and the condenser which may be used in case of accident to the condenser. Speed regulation of the turbines is obtained by a motor governor on each turbine, which is controlled from the switchboard. A small oil pump in the engine room supplies all of the oil necessary for operating the plant.

The normal speed of the alternators is

1500 R. P. M. at 25 cycles. They are delta connected and generate at 6600 volts, their output at normal load being 454 amperes.

The traveling crane is located in the engine room. It is of sufficient size to take the maximum load represented by the heaviest piece of machinery required to be handled, such as the bed plate of an engine. It has complete electrical equipment being operated from the cage of the crane. The motors on the crane are driven from the exciter circuit in order to keep their motors more independent of the main supply.

There are two exciters for the plant, one being motor driven and the other turbine driven. The motor driven exciter is in the engine room, close to the transformer room wall. It is driven by a 150 H. P., 25 cycle, 6600 volt induction motor, the generator rating being 120 K. W.

The other exciter is a 120 K. W. generator coupled to a non-condensing Curtis trubine. The turbine is controlled by a motor governor operated from the control board. The alternators are excited at 125 volts, this voltage being used in order that an excess of storage cells is not needed for this purpose in case of accident to the exciters.

THE ENGINE ROOM BASEMENT

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THE ENGINE ROOM BASEMENT

All auxiliary equipment for the engine room is located in the engine room basement. The auxiliaries are placed so that they can be moved to the open part of the engine room floor and lifted out by the crane without disturbing any other auxiliary. All of the auxiliaries are driven by Curtis turbines except the air pumps which are driven by reciprocating steam engines. An auxiliary steam header located in the engine room basement supplies the steam for the turbines.

The Wheeler horizontal surface condensers are placed directly underneath the turbines. They are supported over a pit two feet deep, in which is placed the three inch two stage turbine driven condensed steam pump. Eighteen inch D. A. volute circulating pumps are used. The water is taken in from the in-

take tunnel and discharged from the condenser into the discharge tunnel. Both of these tunnels are located underneath the basement floor, but they do not interfere with the building foundation.

Wheeler tandem rotative dry vacuum pumps, 9" x 22" x 16", are connected to the condensers at either end.

The exhaust and condensed steam is delivered to the feed water heater in the boiler room through a header located in the boiler room basement.

Two Alberger feed water pumps, each of 7000 boiler horse power capacity, are installed. There are two feed water headers for each row of boilers, one being a main header and the other an auxiliary. The pumps are so connected that either pump will supply the amount of feed water necessary. One header is all that is necessary to supply each row of boilers. In case of an

emergency the main header may be cut out and the auxiliary header can be used. The pumps connect either to the main header or the auxiliary.

The high tension transformers are water cooled, the water being forced in by turbine driven pumps located in the basement. The hot water is discharged into the discharge tunnel.

THE TRANSFORMER COMPARTMENTS

TRANSFORMER COMPARTMENTS

Each alternator has its own set of transformers. The capacity of the transformers is equal to that of the alternator. All are of the single phase type and are connected in delta on both sides. The high tension wires lead directly up through the floor to the bottom of the high tension switches on the gallery above.

THE SWITCH & CONTROL GALLERY

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SWITCH AND CONTROL GALLERY

On the second gallery are located the control board and the G. E., H-3, oil switches.

The control board is of the bench type of marble with black marine finish and consists of four generator panels and two exciter panels. It is located in the center of the engine room which position allows the operator full view over the entire room.

Above each set of transformers are the two H-3 oil switches for that machine, each switch having an overload release.

The transfer bus is in the engine room on the wall separating the engine room from the transformer compartments. Two solenoid operated switches and disconnects for each alternator, are placed directly under the transfer bus and opposite each machine.

The high tension wires are carried up to

the third gallery through enameled brick conduit compartments located at the engine room side of the gallery in front of the switches.

HIGH TENSION GALLERY

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HIGH TENSION GALLERY

On the high tension gallery are the high tension buses, lightning arresters, choke coils, and the wall outlets for the high tension lines. The buses are in compartments against the engine room wall of the gallery.

The choke coils are on the ceiling of the gallery, each coil being in its own compartment.

The lightning arresters are of the aluminum cell type, their rating being 50,000 volts. They are placed close to the outer wall of the building.

The wall outlet consists of a long insulating glass or porcelain tube of small diameter having a very heavy wall which is placed over the wire and passed through a slab of insulation set in the wall of the building, the whole being protected from driving rain by an

extension roof. Both tube and slab should be of fire proof material.

Glass and porcelain are electrically the best materials for insulation, but on account of their lack of mechanical strength even the difference between out-of-door temperature and that inside, will weaken them. For this reason the end strain must be taken up outside the building by a suitable guide pole.

DESCRIPTION OF WIRING

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DESCRIPTION OF WIRING

The general layout of the wiring of the switches and so forth was made as simple and as flexible as possible. It was laid out in such a way so as to avoid any interruption to the service. The apparatus was so arranged so that in case of accident the disabled section could be easily disconnected.

Tracting out the alternator connections the circuit passes from the alternator through a solenoid operated switch, then through disconnects to another solenoid operated switch and to the transfer bus. From the disconnects the circuit passes through the transformers to an H-3 switch and then to the high tension bus. From the high tension bus it passes through another H-3 switch, through choke coils and lightning arresters direct to the line. There are four out-going lines, transmission being effected at

50,000 volts.

The power for the motor driven exciter is taken from the transfer bus. It passes through three switches, automatically inter-locked, and then direct to the motor. The generator current passes through a switch and then directly to the direct current power bus.

The turbine driven exciter conneots directly through a switch to the d. c. power bus. All of the switches are controlled from the control board.

C O N T R O L   B O A R D

CONTROL BOARD

As previously stated, the control board consists of four generator panels and two exciter panels. On the generator panel are three ammeters, a power recording wattmeter, a power indicating wattmeter, a power factor meter, a field ammeter, two receptacles, one for voltage plugs and the other for synchronizing plugs, five control switches and a red lamp for indicating overloads. Four of the control switches are used in operating the two H-3 switches and the two solenoid operated switches. The other is used to connect the field of the alternator in circuit. The two double pole double throw switches are used for connecting the field rheostat in circuit and the motor governor for the turbines.

Control, synchronizing, voltage and d.c. power buses are located on the back of the board.

The synchroscope is on a bracket at the end of the board. Synchronizing is effected by pluging into the synchronizing receptacle of the machine which is to be synchronized and the effect noted on the synchroscope. The voltmeter is also at the end of the board and the voltage may be obtained in a similar manner.

The motor driven exciter panel contains an ammeter, voltmeter and two receptacles, one for the voltage plugs and the other for the ground detector plugs. It also contains two control switches, one for controlling the three interlocking switches and the other for connecting the generator to the d. c. power bus. The double pole double throw switch is used to connect the field rheostat in circuit.

On the turbine driven exciter panel are an ammeter, ground detector and receptacles for voltage plugs and ground detector plugs. It also

has two control switches, one for the connection to the d. c. power bus and the other controlling the equalizer connection between the generators. The double pole double throw switches are used in controlling the field rheostat and the motor governor for the turbine.

On the back of the exciter panels is a ground detector bus and a voltage bus in addition to the control and d. c. buses. For this reason only one ground detector and one voltmeter need be used.

A P P E N D I X

B I B L I O G R A P H Y

Collins, H. E.

Steam Turbines.

Power Catechism.

Koester, Frank

Design of Power Plant.

Weingreen, J.

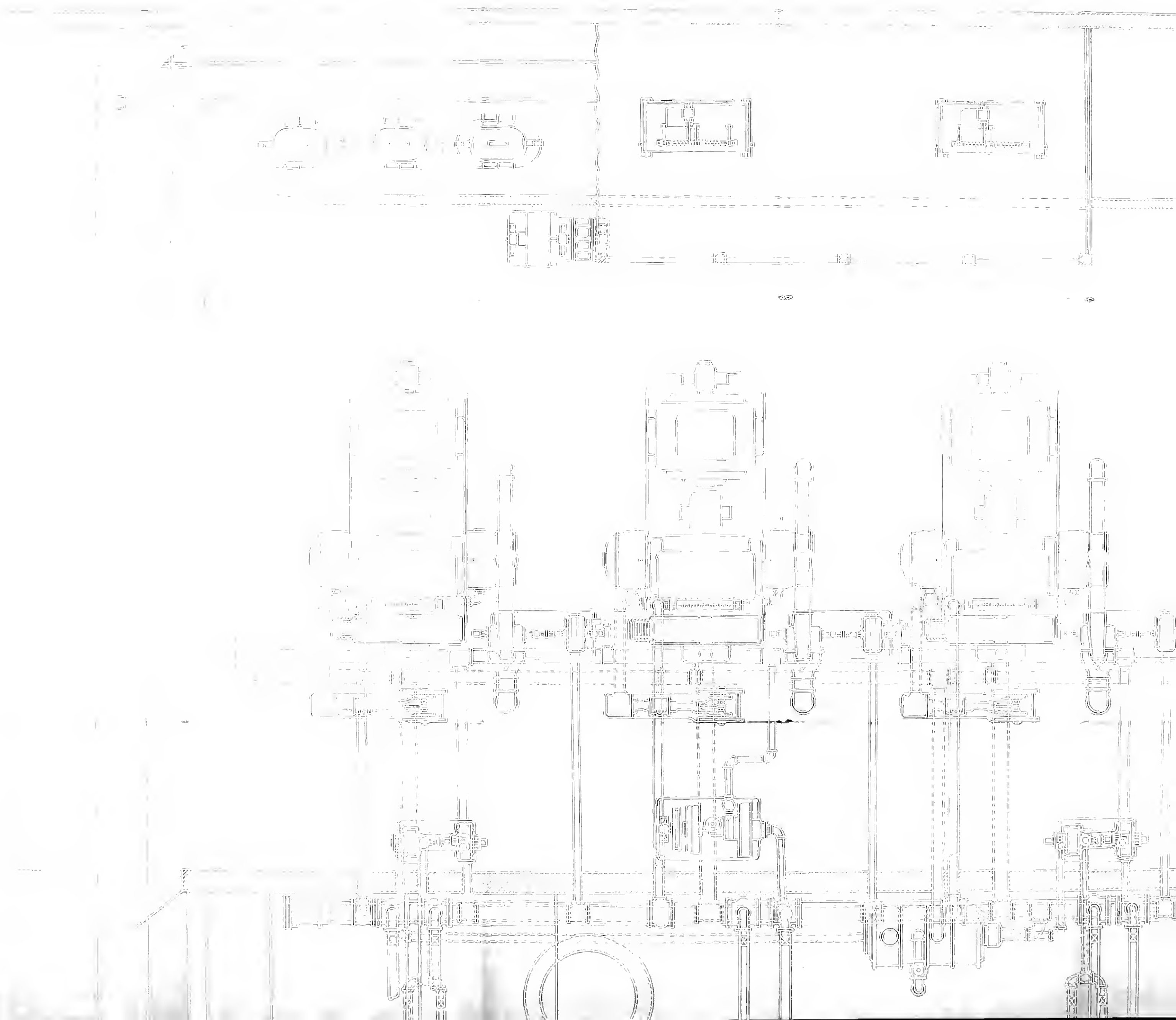
Electric Power Plant Engineering.

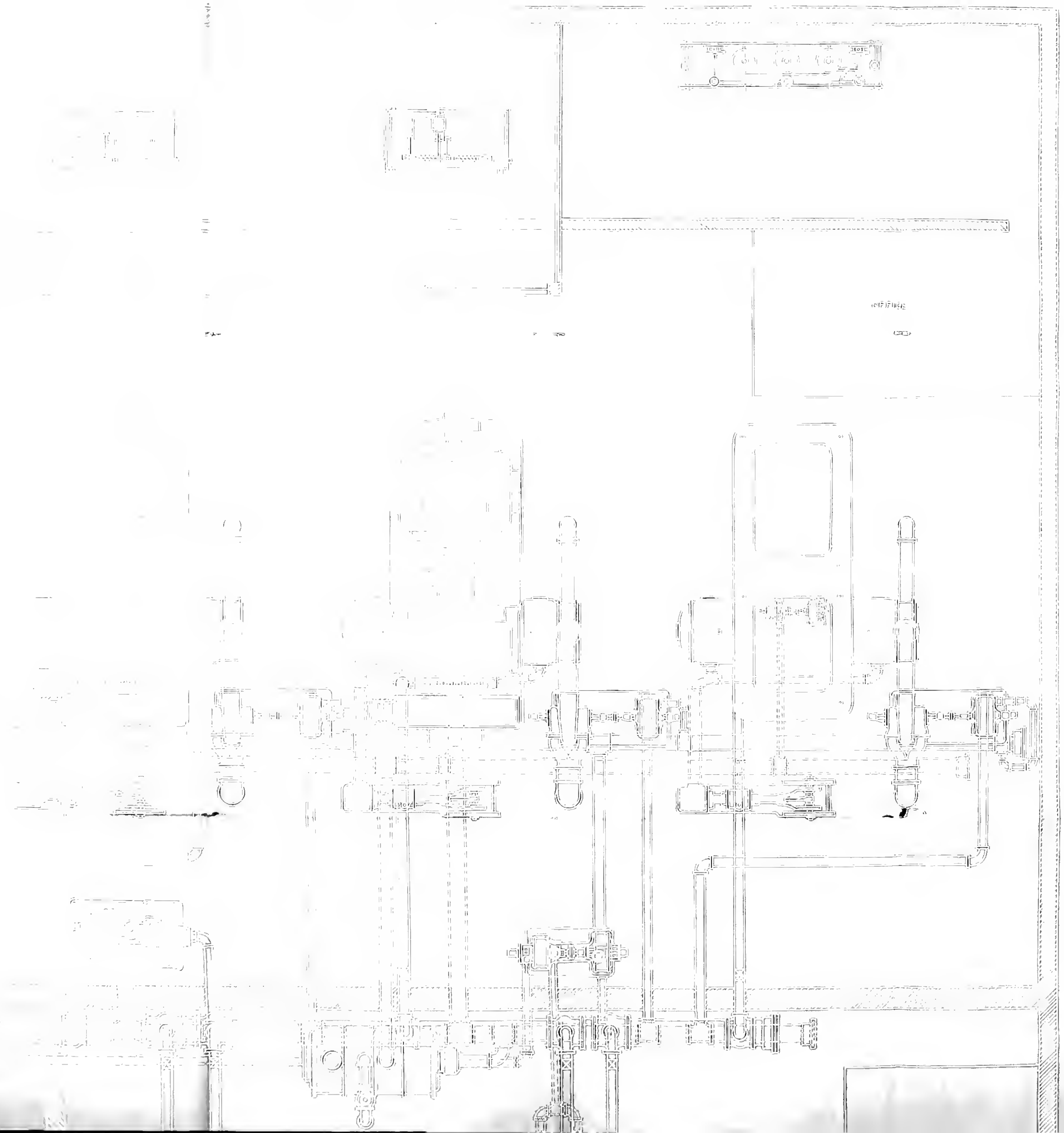
Snell, John F. C.

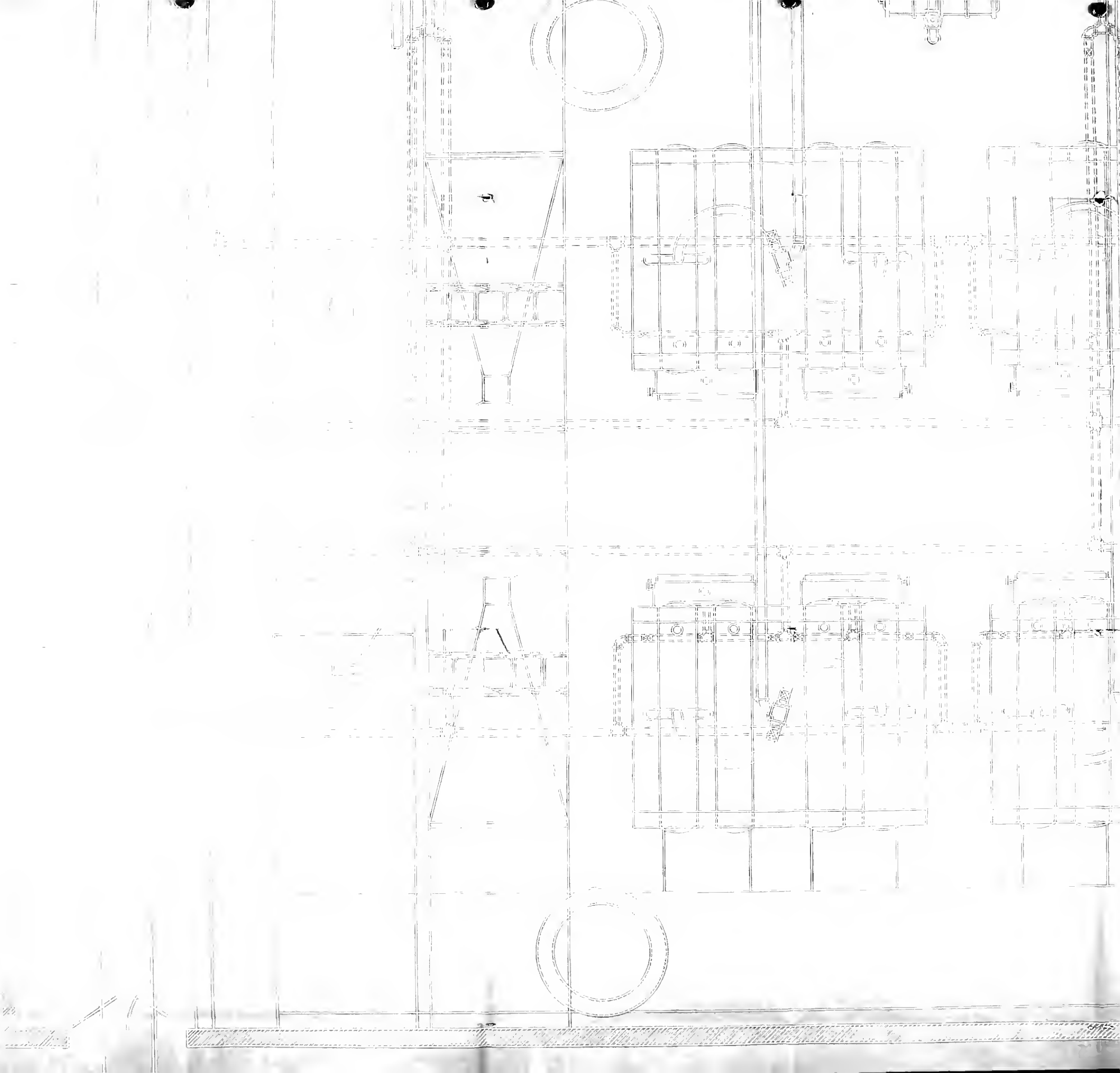
Power House Design.

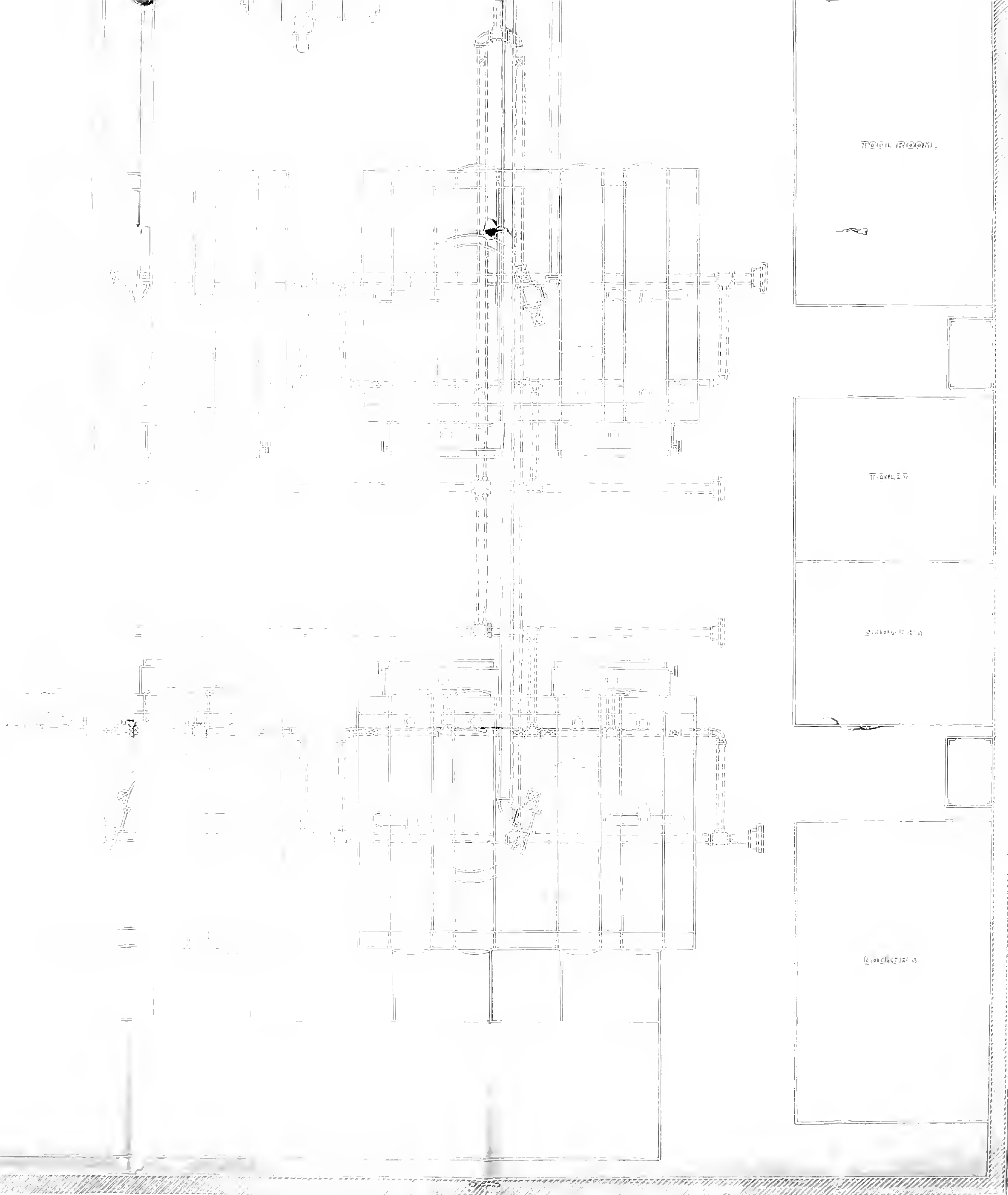
Gebhardt, G. F.

Steam Power Plant Engineering.









PLAN VIEW

FOR

3000 KILO-WATT

TURBO-ELECTRIC POWER STA

DRAWN BY [illegible] CHECKED BY [illegible]

TRACED BY [illegible] MAY, 1915.

SCALE = $\frac{1}{4}$" = 1 ft.

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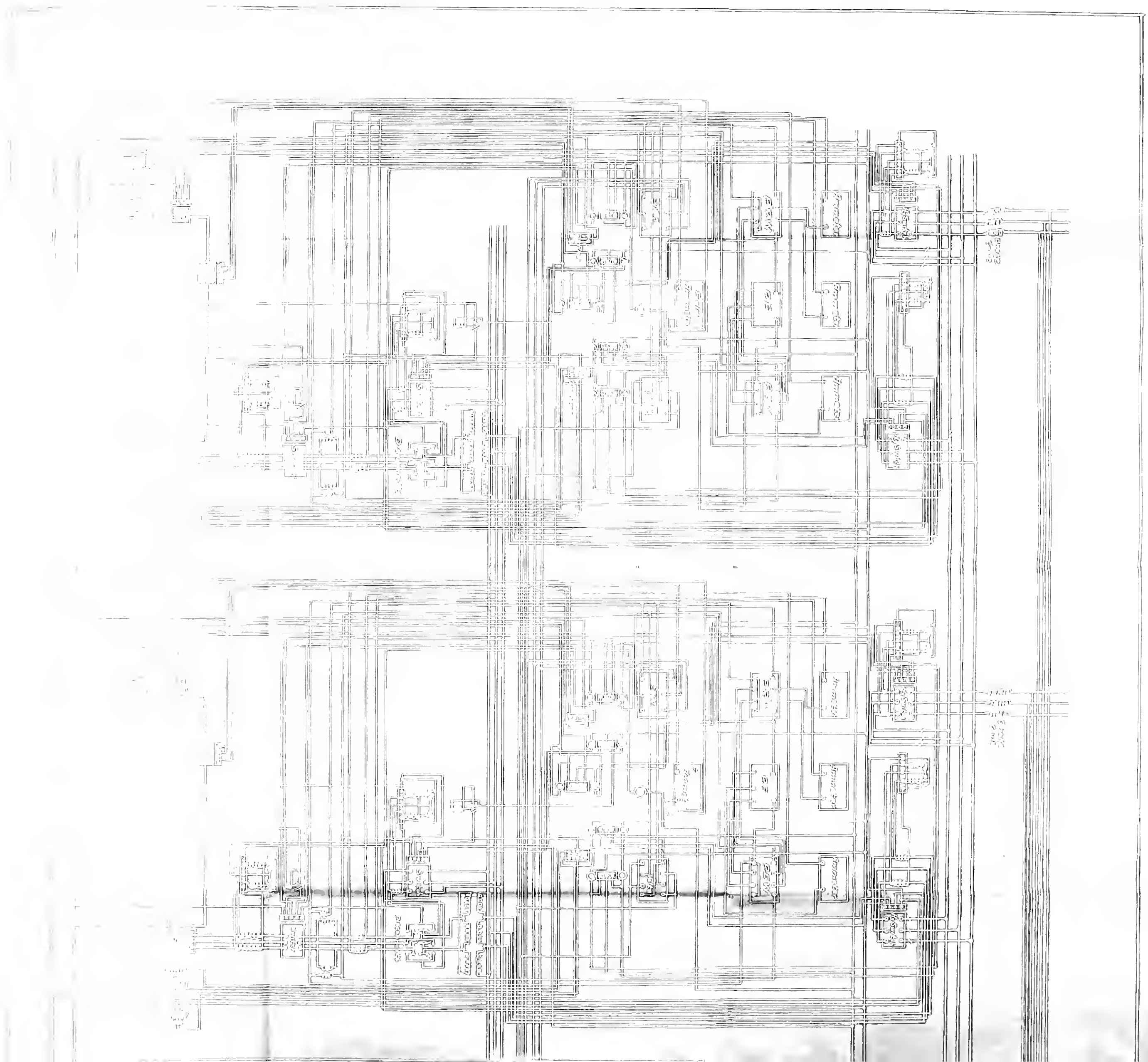

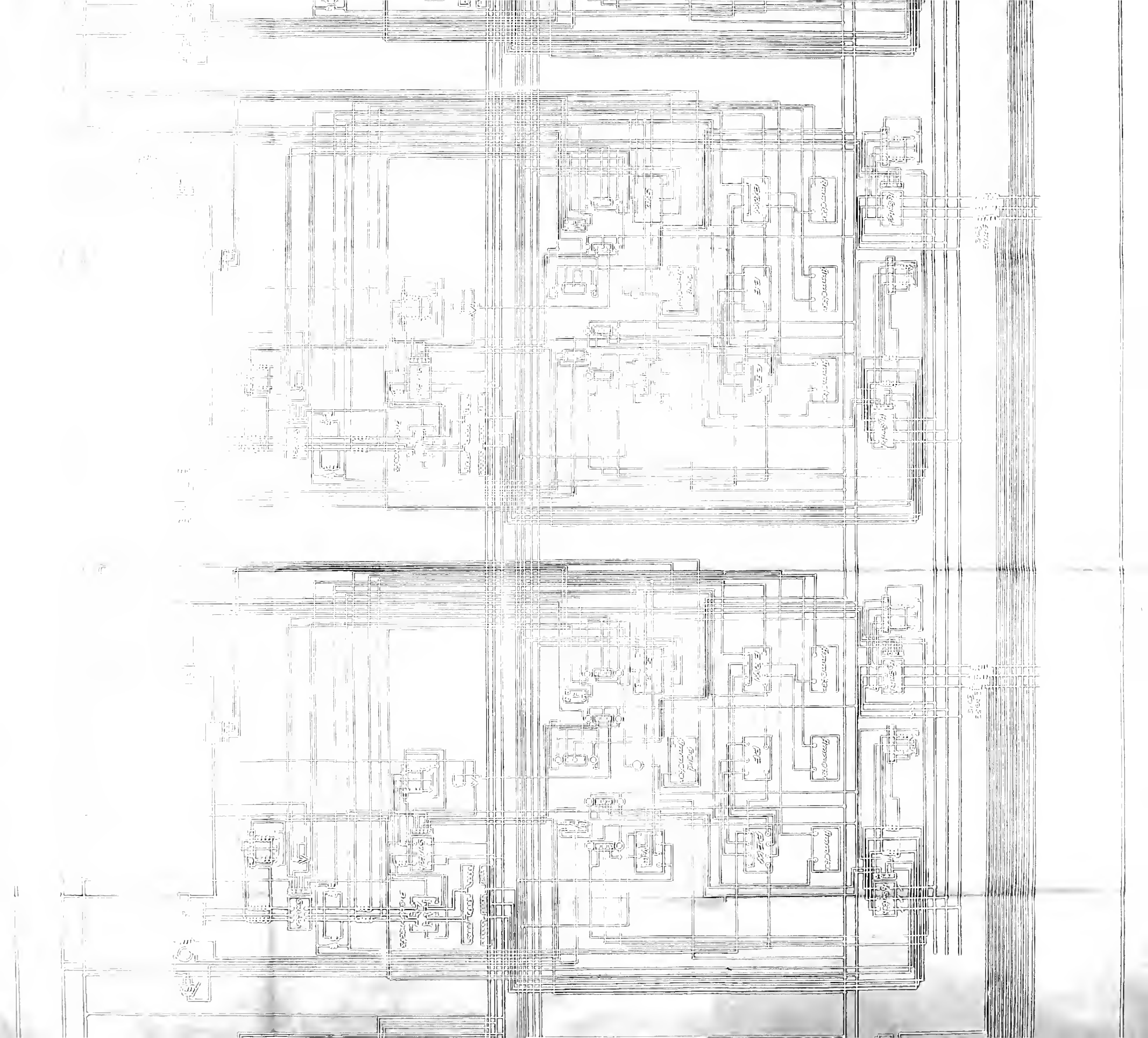

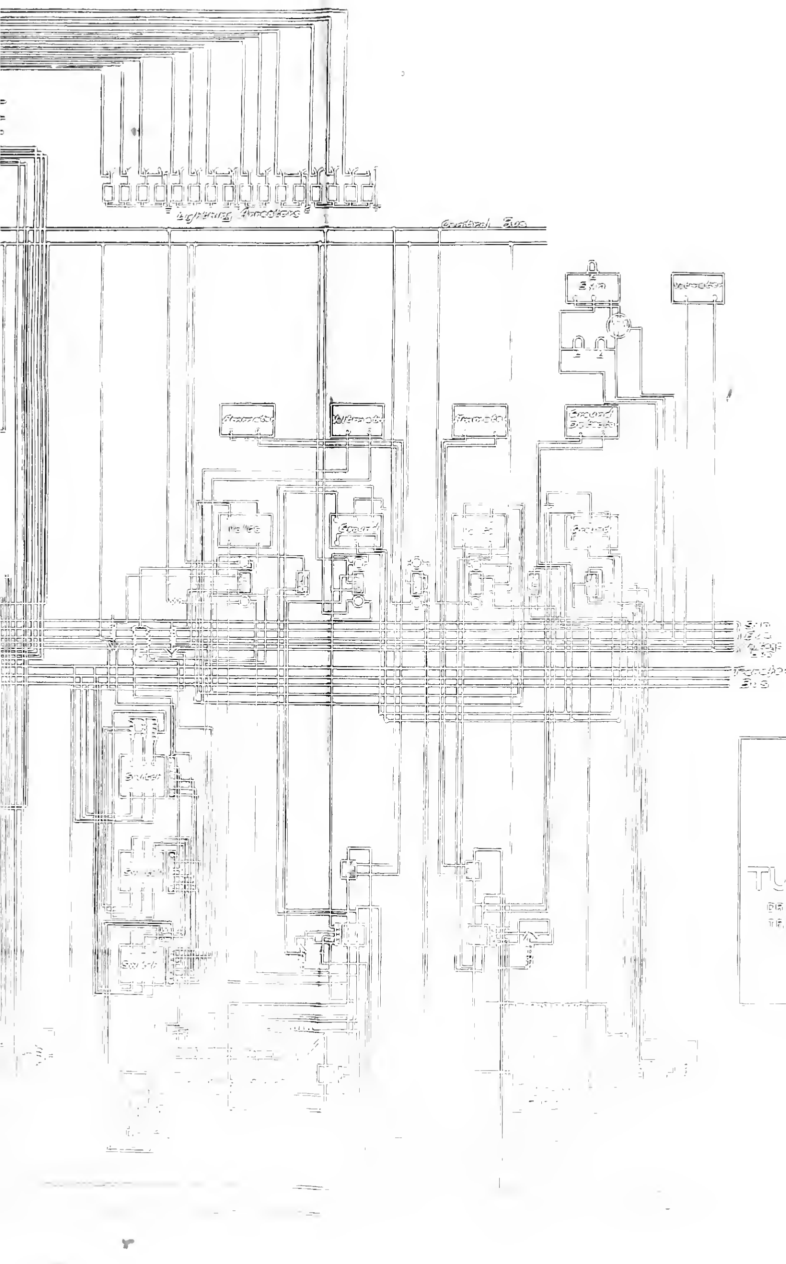

WIRING DIAGRAM

FOR

8000 KILO-WATT

TURBO-ELECTRIC POWER STA.

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SECTIONAL VIEW

FOR

8000 KILOWATT

TURBO-ELECTRIC POWER STA.

DRAWN BY [illegible] CHECKED BY

TRACED BY [illegible] MAY [illegible]

SCALE = $\frac{1}{4}$" = 1 FT.

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